KING COUNTY CONVEYANCE SYSTEM IMPROVEMENT PROJECT

CONVEYANCE SYSTEM COST SYSTEM PIPE COST PARAMETERS

FINAL REPORT

SEPTEMBER 2001

HDR

in association with

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and

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INTRODUCTION

The purpose of this memo (originally written in 1999) is to describe the pipe costs part of the King County Wastewater Treatment Division (KCWTD) Conveyance System Construction Cost Model. The purpose of this pipe cost model is to “bridge the gap” between Preliminary/Order of magnitude cost estimates typically issued in planning level reports an more accurate estimates that prepared at the predesign level. This model will be used to develop refined planning level cost estimates for KCWTD gravity sewers and force mains.

This memo includes specifics on the structure of the pipe cost module. A more general discussion of the purpose of the model is included in the September 2001 *Conveyance System Cost Estimates – Task 250 Report.*

PIPE COST MODEL

The pipe cost model will be structured to provide the user with a formatted means of data entry and a formatted output for incorporation into other cost estimating models. The relationship between this model and other cost models is detailed in the Figure 1. The basic format for the data input is include in Appendix A.

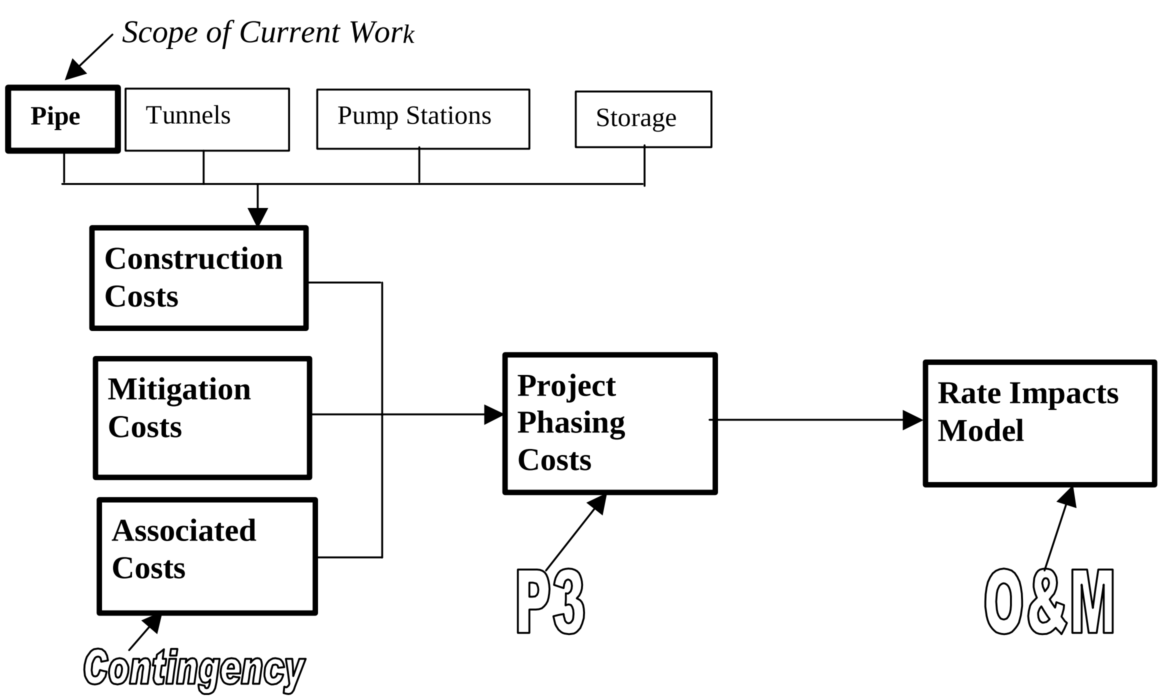

Figure 1. Cost Development Relationships

Initial Input Data

The introduction screen of the cost model shows the cost basis month and year for the base unit costs contained within the model. This screen, which is included in Appendix A, also provides the Engineering News Record Seattle Construction Cost Index (ENR Seattle CCI) for the base month and year. To escalate model costs to the current month and year, the user must input the current ENR Seattle CCI. Estimated costs to the current year are escalated by the ratios of the ENR Seattle CCI. To calculate future construction costs, the user must also enter the current month and year and an estimated annual cost escalation percentage rate. Current costs are then adjusted by the user entered annual escalation rate multiplied by the number of years and/or partial years between the current month/year to the construction month/year to determine future year construction costs. The future escalation cost will be based on the annual average increase in the ENR Seattle CCI for the previous five years but could be overridden by the user.

GRAVITY SEWER/ FORCE MAIN COST MODEL

The construction costs of gravity sewers and force mains are influenced by a number of factors including type of pipe, depth of cover, suitability of native backfill, and dewatering requirements. These and other factors were incorporated into this model component, providing user flexibility to adjust for site specific conditions and design criteria that will likely be known at the planning level.

The cost model parameters were divided into fixed imbedded parameters and adjustable project specific parameters that are entered by the user. Default values are included for most parameters for use when the user does not know these values at the time of the planning level estimate. All the values include herein include contractor overhead and profit.

Fixed Model Parameters

Fixed parameters are imbedded in the model and can not be modified by the user. These fixed parameters reflect unit prices for the base model month and year as shown on the introduction screen. They can only be modified by the model caretaker with password access. This would typically be done as part of adjusting the model cost base month and year and adjusting the ENR Seattle CCI. Otherwise, these imbedded costs are not expected to vary significantly between projects. Table 1 lists those cost items with imbedded unit costs or percentage used in the initial model.

It is assumed that ductile iron pipe will be used for force mains and Class V reinforced concrete pipe (RCP) will be used for gravity sewers. Based on this assumption, the outside diameter (OD) of various nominal pipe sizes could be determined. This information along with pipe costs are summarized in Table 2.

Table 1. Fixed Input Parameters
December 1999 (ENR Seattle CCI = 7,137)

Items	Units	Assumption/Unit Cost
Mob/demob	LS	10%
Trench Safety (Box)	SF	$0.50
Special Shoring	SF	$8
Excavation	CY	$10
Imported Backfill	CY	$25
Place Native Backfill	CY	$5
Spoil Load and Haul	CY	$10
Half-Width Residential Paving	FT	14
Half-Width Collector Paving	FT	18
Half-Width Arterial Paving	FT	22
Full-Width Residential Paving	FT	28
Full-Width Collector Paving	FT	36
Full-Width Arterial Paving	FT	44
Asphalt Paving (Trench)	SY	$50
Asphalt Paving (Beyond Trench)	SY	$20

Table 2. Pipe Material and Installation Costs
December 1999 (ENR Seattle CCI = 7,137)

Pipe Dia. (in)	Standard Force Main (DI) [1,3] ($/lf)	High Head Force Main (DI) [2,3] ($/lf)	Outside Dia. (in)	Gravity Sewer[3] (RCP) ($/lf)	Outside Dia. (in)	Installation Cost ($/lf)
8	11	15	9.05	10	10.5	10
10	14	20	11.10	12	12.5	12
12	18	25	13.20	15	17	15
14	23	32	15.30	NA	NA	18
15	NA	NA	NA	18	20	20
16	26	38	17.40	NA	NA	22
18	30	44	19.50	23	23	25
20	35	50	21.60	NA	NA	26
21	NA	NA	NA	26	26.5	27
24	43	65	25.80	30	30	30
27	NA	NA	NA	36	33.5	35
30	80	110	32.00	50	37	40
36	108	150	38.30	60	44	54
42	140	185	44.50	78	51	60
48	200	240	50.80	105	58	72
54	250	315	57.76	150	66.5	100
60	315	390	61.61	190	73.5	120
72	NA	NA	NA	240	87.5	160
78	NA	NA	NA	280	93	180

(continued)

Table 2. Pipe Material and Installation Costs (continued)

Pipe Dia. (in)	Standard Force Main (DI) [1,3] ($/lf)	High Head Force Main (DI) [2,3] ($/lf)	Outside Dia. (in)	Gravity Sewer[3] (RCP) ($/lf)	Outside Dia. (in)	Installation Cost ($/lf)
84	NA	NA	NA	360	100	200
96	NA	NA	NA	440	115.5	240
108	NA	NA	NA	540	128	280
120	NA	NA	NA	720	140	360
144	NA	NA	NA	1050	168	480

Notes:
(1) Standard force main would be for most applications where the maximum hydraulic transient is less than 250 psi.
(2) High-head force main would be used where high hydraulic transients are expected.
(3) DI pipe and RCP come in different standard sizes. Sizes not available are noted.

User Input Parameters

The model is configured to allow for a variety of site conditions by adjusting certain input parameters. These project specific input parameters and the default values are summarized in Table 3. In some cases, there will be construction costs that are unique to a given project. These cost may include special landscaping requirements, artwork, unique street improvements, and other miscellaneous costs. To account for these costs at the planning stage, the user would be allowed to input a fixed dollar amount that would be calculated separately by the user. Typical input screens are included in Appendix A.

Table 3. Project Specific Input Parameters

Parameter	Options	Default
Pipe Segment	User must input segment name	Must be input by user
Construction Month/yr.	User may select different construction year	Current Year
Pipe Inside Diameter	8-144 inches	Must be input by user
Segment Length	Total segment length in feet	Must be input by user
Pipe Use	Gravity Sewer (concrete); Force Main (ductile)	Gravity
Average Depth of Cover	User selected in 1-ft increments from 4-40 ft.	12
Trench Backfill	Native; Imported	Imported
Manhole Spacing	Close (250’); Medium (500’); Far (1,000’)	Medium
Existing Utilities	None; Average; Complex	Complex
Dewatering	None; Minimal; Significant	Minimal
Pavement Restoration[1]	None; Rural; Urban, Full Width (specify width)	Urban
Traffic	None; Light; Heavy	Heavy
Shoring	Standard; Special	Standard
Unique Project Costs	User must input a cost number	0
R/W Required	None; Rural; Urban	None

Notes:
(1) For typical trench restoration. Half pavement width and full pavement width replacement may be required and should be computed separately. Check with local municipalities for restoration requirements.

Trench Characteristics

The trench section is determined by pipe diameter, type of pipe, number of pipes, and depth of cover. The resulting trench dimensions along with a selection of the type of trench backfill are used to determine the volumes of excavation and native or imported backfill as well as input to determine the surface restoration area.

Based upon a review of past King County projects and construction methods, it was assumed that trench box construction would be used to maintain approximately vertical sidewalls and minimize trench excavation and backfill volumes. With user input of pipe characteristics, the trench width is automatically calculated. The width varies with pipe outside diameter and is calculated using the formula:

$$\text{Trench Width (W in feet)} = 1.3 \times OD + 2.5$$

where OD is the outside pipe diameter in feet. See Figure 2 for a cross-sectional detail of a pipe trench. For an 8-inch ductile iron pipe, this results in a trench width of 3.5 feet. For a 12 foot diameter (14 feet OD) concrete pipe, the trench width is 20.7 feet. The increasing trench widths allow for the use of a trench box and provides a minimum clearance on each side of the pipe for compaction of the pipe zone material.

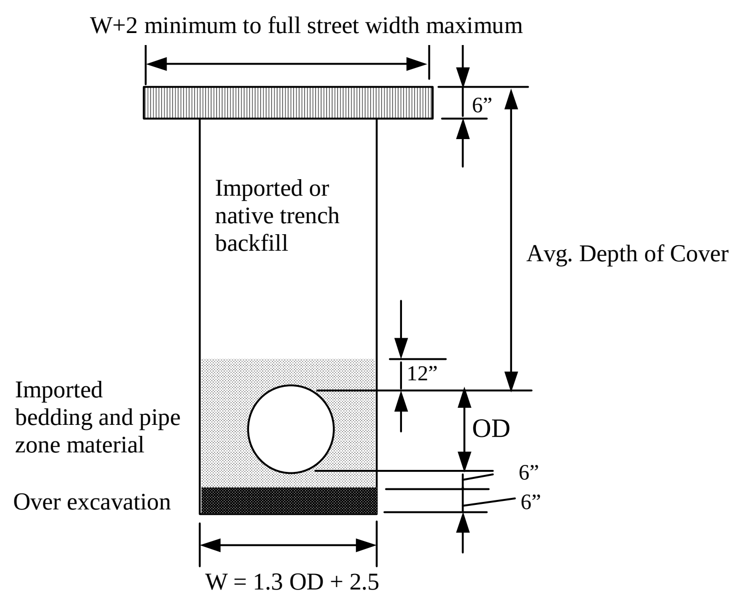

Figure 2. Trench Geometry

It was assumed that the pipe bedding and pipe zone backfill would be imported granular material. The trench backfill above the pipe zone can be selected by the user to be either imported or native material. The default setting is imported trench backfill.

A similar trench geometry was used for parallel pipes. The user can select a combination of pipesizes and the trench width is automatically calculated. The width varies with pipe outside diameter and is calculated using the following formulas:

$$\text{Clearance between pipes (CLR in feet)} = 0.15 \times (OD_1 + OD_2) + 1$$

$$\text{Trench Width (W in feet)} = 1.25 \times (OD_1 + OD_2 + CLR) + 1$$

where OD_1 and OD_2 are the outer diameters of the two pipes. These parameters were developed following a review of a number of KCWTD projects that included parallel pipes. For example, the trench width for parallel 24 inch force mains would be approximately 9.4 feet, and there would be 21 inches clearance between the two pipes.

Pipe Characteristics

The user inputs the nominal pipe design diameter, pipe use (gravity sewer or forcemain), and total length of installed pipe. For this cost model, it was assumed that Class V reinforced concrete pipe (RCP) would be used for gravity sewers and Class 53 Tyton Joint ductile iron (DI) pipe would be used for most force mains, with restrained joint pipe used for high head applications. Pipe wall thicknesses vary with pipe material and diameter. These resulting pipe ODs are tabulated within the model and are used to determine trench widths. The information used to develop the initial model pipe wall thicknesses and material costs is shown on Table 2. The tabulated installation costs were based on the labor and equipment costs in *Means 2000 - Site Work and Landscape Cost Data*, which were escalated by 50 percent to account for the higher construction costs in the Seattle area.

If the depth of cover over the pipe can be estimated due to known conditions, the user can select the average depth of cover for the pipe segment. If the user makes no selection, the cost model will default to 12 feet, a typical average depth of cover.

The cost for manholes was developed from past bid tabs and correlated with pipe size. These manhole costs and the relationship between the manhole size and pipe diameter are summarized in Table 4. The maximum hole size in the manhole is typically the outside diameter of the pipe plus the wall thickness of the manhole. It was assumed manholes would not be provided with plastic liner plate for corrosion resistance.

Table 4. Manhole Sizes and Costs

Manhole Diameter (in)	Pipe Diameter(s) (in)	Base Cost[1,2] ($/each)	Additional Cost[1,3] ($/each)
48	<21	3,000	250
54	24-27	5,000	300
72	30-42	9,000	500
84	48	12,000	700
96	54-60	16,000	900
108	66-72	20,000	1,200
120	78	26,000	1,600
144	84-96	32,000	2,000

Notes:
(1) Costs based on ENR Seattle CCI = 7,137 for December 1999.
(2) Based on 6 to12-foot pipe cover.
(3) Cost for each additional foot of depth beyond 12 feet of cover.

Right of Way

It is anticipated that in most cases, force mains and gravity sewers will be constructed within the existing street right-of-way. In some instances, the acquistion of permanent easements, temporary construction easements, and tunneling easements may be required. The costs for easements and acquisitions were developed from information from previous County projects. These easement and acquisition costs are summarized in Table 5. Minimum easement widths are summarized in Table 6.

Table 5. Right-of-Way Acquisition and Easement Costs

Area	Property Acquisition Cost[1] ($/sf)	Permanent Easements[1,2] ($/sf)
Residential	$22	$7
Industrial	$10	$3
Office/Commercial	$20	$6

Notes:
(1) Costs based on ENR Seattle CCI = 7,137 for December 1999.
(2) Acquisition and easement costs are based on an undated memo from William Wilbert to Ed Cox RE: Value Estimates for Property Types.

Table 6. Minimum Easement Widths

Pipe Depth (ft)	Easement Width (ft)
<12	20
12-20	30
>20	50

Existing Utilities

In most developed areas there will be existing utilities that may interfere with a proposed pipe alignment and make construction difficult, if not impossible. These conflicts will be most prevalent in urbanized areas. There are three options to accommodate different levels of utility conflicts. The degree of potential utility conflict is also expected to increase slightly with greater trench width. The estimated values to accommodate for existing utilities are summarized in Table 7.

Table 7. Utility Conflict Costs

Pipe Dia. (in)	Utility Conflict	
	Average[1] ($/lf)	Complex[1] ($/lf)
8-12	20	40
14-18	30	60
20-30	40	80
36-42	50	100
48-54	60	120
60-66	80	160
72-78	100	200
84-96	120	240
108-144	150	300

Notes:
(1) Costs based on ENR Seattle CCI = 7,137 for December 1999.

Dewatering

The amount of dewatering will be dependent upon geotechnical conditions and the depth of the groundwater table in comparison to the bottom of the trench. Where the groundwater is near the surface, it is anticipated that significant dewatering will be required. This dewatering would include either the construction of a wellpoint dewatering system or the use of dewatering wells. Where minimal dewatering is required, it was assumed trench sumps would be employed. Based on a review of past projects and discussions with geotechnical engineers, typical costs for trench sumps range from $20-$40 per linear foot of trench while typical costs for dewatering wells range from $50-120 per linear foot of trench. Table 8 lists the increasing costs for dewatering as a function of pipe diameter.

Table 8. Dewatering Costs

Pipe Dia. (In)	Trench Sump Dewatering[1] ($/lf of trench)	Dewatering Wells[1] ($/lf of trench)
8-12	20	50
14-21	20	60
24-30	20	70
36-48	30	80
54-66	30	90
72-84	40	100
90-96	40	110
108-144	40	120

Notes:
(1) Costs based on ENR Seattle CCI = 7,137 for December 1999.

Traffic Control

For most projects, traffic control will be required. The cost of traffic control will, in most cases, be greater for projects in the vicinity of arterials and other high traffic areas. Costs for traffic control were estimated based on information from previous projects (Table 9).

Table 9. Traffic Costs

Pipe Dia (In)	Level of Traffic	
	Average[1] ($/lf of trench for traffic control)	Heavy/Special[1,2] ($/lf of trench for traffic control)
8-21	$5	$10
24-42	$10	$20
48-66	$12	$24
72-90	$15	$30
96-144	$15	$30

Notes:
(1) Costs based on ENR Seattle CCI = 7,137 for December 1999.
(2) The cost for heavy/special traffic was estimated as twice the average cost for traffic control.

Calculations

Material quantities and construction costs were developed based upon the trench geometry and input parameters described previously. These volume calculations are summarized in Appendix B.

Outputs

The output from the model will summarize the input parameters and model outputs in a spreadsheet format that can exported into other King County cost model components. An example of the proposed formatted output is included in Table 10.

Table 10. Example of Tabular Output
December 1999 (ENR Seattle CCI = 7,137)

Project Name	Pipe Dia (in)	Pipe Length (ft)	Pipe Type	Depth	Parallel Pipe (Y/N)	R/W	Backfill
Small trunk	48	1,000	SS	Deep	No	None	Native
Large trunk	64	1,000	SS	Deep	No	None	Native
Forcemain	24	1,000	FM	Med	No	Urban	Import
Local sewer	8	100	SS	Med	No	Rural	Import

Table 10. Example of Tabular Output (continued)

Project Name	Existing Utilities	Pavement Restoration	Dewater	Traffic	Unit Cost ($/lf)	Total Cost
Small trunk	None	No	Wells	None	599	$599,000
Large trunk	Average	Yes	Sumps	Light	999	$999,000
Forcemain	Average	Yes	Sumps	Light	399	$399,000
Local sewer	Average	Yes	Sumps	Heavy	99	$9,900

APPENDIX A
PROPOSED COST MODEL INPUT SHEETS

APPENDIX B
PROPOSED COST MODEL
VOLUME AND OTHER CALCUALTIONS